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PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Takao ABE et al.

Group Art Unit: 1765

Application No.: 09/743,982

Examiner: M.A. Anderson

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Docket No.: 108360

For: SILICON SINGLE CRYSTAL AND WAFER DOPED WITH GALLIUM AND METHOD FOR PRODUCING THEM

DECLARATION UNDER 37 C.F.R. §1.132

Director of the U.S. Patent and Trademark Office
Washington, D.C. 20231

Sir:

I, Takao Abe, a citizen of Japan, hereby declare and state:

1. I have a doctoral degree in Engineering, conferred upon me by the Faculty of Engineering of Hokkaido University in Japan in 1985.

2. I have been employed by Shin-Etsu Handotai Co., Ltd. since 1964 and I have had a total of 40 years of work and research experience in dislocated and dislocation-free silicon single crystals. The growing mechanism of intrinsic point defects and the suppression of point defects by doping nitrogen are particular subjects of my research. For these results, the Japan Association of Crystal Growth gave me the Paper Award in 1991. The demonstration of gallium-doped CZ crystals for solar cell application is one of these results. I have also performed research in the field of silicon-on-insulator structures created by wafer bonding techniques. These silicon-on-insulator structures are used for advanced ULSI devices. In addition, for mass production, I have contributed to developments

regarding the growth of dislocation-free FZ and CZ crystals, as opposed to dislocated crystals, and larger diameter FZ and CZ crystals from 10 mm FZ to 300 mm CZ crystals. Regarding other wafering processes, I developed, 15 years ago, new surface grinders to create flatter surfaces for bonded silicon-on-insulator wafers. These surface grinders are now popular in wafer technology. I was also involved in the development of many evaluation and characterization processes and equipment. The Solid State Materials and Devices (SSMD) Award was given by the Japanese Society of Applied Physics for the evaluation work by the technique of photoluminescence in cooperation with the public institution in 1992.

3. I am a member of the Electrochemical Society, the Japanese Society of Applied Physics and the Japanese Society of Physics. I was a co-organizer and co-chairman of the Silicon Materials Symposium and the Semiconductor Wafer Bonding Symposium from 1977 until 2002 in the Electrochemical Society Meetings held in the United States.

4. I have published numerous papers in this field, and applied for patents in the United States, Japan and other countries. In total, I have published more than 30 research papers in Japanese and more than 60 in English. A representative list of my English language publications related to silicon-on-insulator technology is attached hereto as Exhibit A.

5. I have applied for over 80 patents in Japan, and over 40 in the United States, of which 10 have been issued, and I have filed more than 200 other foreign applications.

6. In September of 1999, I participated in a conference, the 11th International Photovoltic Science and Engineering Conference ("PVSEC-11"), and published the paper presented there in the Technical Digest of the International PVSEC-11. This paper, Saitoh et al., *Light Degradation and Control of Low-Resistivity CZ-Si Solar Cells*, Technical Digest

of the International PVSEC-11, Sapporo, Hokkaido, Japan, 1999, presented my findings, the subject matter of the claims of the above-captioned patent application, that a gallium-doped silicon single crystal wafer can overcome the problem of photo-degradation occurring on a boron-doped wafer, and these wafers can be made into solar cells having a large area and high conversion efficiencies. This paper received a special award for excellence at PVSEC-11, given to the best research paper presented at the Conference. In addition, a number of researchers, representing various research institutes and listed on the paper, confirmed the results, which are internationally recognized.

7. After PVSEC-11, two papers were published by researchers at the Fraunhofer-Institute for Solar Energy Systems in Germany. I had asked these researchers to evaluate my findings, and these papers summarize the evaluation of my research as it relates to the conversion efficiencies and areas of gallium-doped silicon single crystal wafers. Conversion efficiencies of 22.5% and 20.2% for 2 x 2 cm^2 and 10 x 10 cm^2 gallium-doped silicon wafers respectively were reported in those papers. The results were surprising because it was known that the efficiency generally decreases as the area of a wafer increases. A conversion efficiency of 20% or more can not be achieved for a boron-doped silicon single crystal wafer having an area of 10 x 10 cm^2. The papers report the surprising result that a conversion efficiency of 20% or more was, for the first time, achieved for a gallium-doped silicon single crystal wafer with a large area.

8. I found, for the first time, that for solar cells made from gallium-doped CZ silicon single crystals, the conversion efficiency distribution has a peak in the range of 5 Ω cm to 0.1 Ω cm as shown in Figure 4 of the present application. This defines a narrower range of resistivities than had been known in the art. My research revealed that a resistivity of more than 5 Ω cm is unnecessarily high, and the conversion efficiency may be reduced

due to internal resistance. In addition, if the resisivity is less than 0.1 Ω cm, the lifetime of the minority carrier will decrease due to Auger recombination, and the conversion efficiency will decrease. Thus, I found that a critical range of resistivities for a gallium-doped CZ silicon single crystal wafer is from 5 Ω cm to 0.1 Ω cm, and that crystals in this range have high conversion efficiencies and can have no photo-degradation.

9. I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine and/or imprisonment under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing therefrom.

Date: April 28, 2003 Takao Abe

Takao Abe